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AN APPLICATION OF DISCRIMINANT ANALYSIS TO THE PROBLEM OF ASSIGNING VARIABLE REENLISTMENT BONUSES

by

Sheldon E. Haber

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0. Introduction

In the past several years much attention has been given to the impact of monetary incentives on enlistments and reenlistments. Relatively little attention, however, has been given to policies and/or procedures for improving the effectiveness of monetary incentives. One such incentive, for example, is the variable reenlistment bonus (VRB). As defined in [4, p. 7514], a variable reenlistment bonus is a "payment awarded to enlisted members serving in a designated critical military skill upon their first reenlistment . . . [which is] designed to provide additional financial incentive for the retention of . . . men in shortage skills [requiring] long and costly training." The same source states the variable reenlistment bonus is to "assist in attaining and sustaining career manning levels in critical military specialties with inadequate first-term retention rates."

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The variable reenlistment bonus, which can be as large as $8,000, is payable in yearly equal installments to individuals in specified occupations who are entitled to a first regular reenlistment bonus.[1] Even though the variable reenlistment bonus constitutes a small portion of total military pay and allowances, about $220 million in fiscal year 1973 [4, 7507-9], it is an important monetary incentive since it is one of only a few forms of compensation which permit direct occupational wage differentials within the military. Moreover, the VRB is likely to become more important in the future as the military adapts to the all-volunteer environment.

Although a number of important issues can be raised regarding the variable reenlistment bonus, e.g., is it effective and what is the optimum sum of money to be devoted to this type of monetary incentive, the primary objective of this paper is more modest. A much simpler problem is examined, namely, the problem of identifying the criteria used by the Navy in assigning VRBs. In pursuing this objective, which is a preliminary step toward possible improvement in the assignment of VRBs, we also examine the problem of measuring labor market balances among military occupations.

The grouping of military skills in terms of their criticalness for the purpose of assigning a variable reenlistment bonus is not an easy task since criticalness is not a single-dimensional quality. As indicated by the cited quote, an important criterion for determining if a particular skill is a critical one is whether there is a shortage of personnel in the skill. The formulation of shortage measures, however, can be as difficult as the formulation of measures of criticalness. For this reason, the measurement of personnel shortages is a crucial aspect of the VRB assignment problem.

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[1] Regular reenlistment bonuses are lump sum payments awarded to enlisted personnel to induce them to reenlist. Unlike regular reenlistment bonuses which may be offered at the completion of any contract term, the VRB, which is an extra bonus, can be offered only during the first reenlistment.

One measure employed in identifying military skills with a shortage of personnel is the career manning ratio. This measure is defined by the Department of Defense as the ratio of career personnel to programmed requirements for personnel in rank E-5 and above. Typically, a careerist is defined as an individual who signs a second reenlistment contract. But in the career manning ratio measure, any individual with more than four years of military service is denoted as a careerist. The numerator of the career manning ratio provides a measure of the supply of career personnel in a skill rating. The denominator, by focusing on rank E-5, a rank generally attained by personnel with more than four years of service but also attained by individuals with less than four years of service, provides a measure of the demand for career personnel. A ratio equal to or in excess of 1.0 is taken to imply a surplus of career personnel; a ratio less than 1.0 is taken to mean a shortage of career personnel.

The emphasis given to the career manning ratio suggests that the function of the VRB is to reduce the turnover rate in military specialties where the outflow of personnel is relatively high. An alternative and more reasonable approach to remedy personnel imbalances, however, would be to use the VRB to reduce the turnover rate in military specialties where the total supply of personnel is inadequate to meet the overall requirement. In the latter approach, the supply of manpower is not limited to careerists in measuring labor balances in an occupation, but would include all personnel trained in an occupational area irrespective of length of service. Correspondingly, the demand for personnel would include all personnel qualified in a skill specialty. It should be noted that as of 30 June 1971 (the date of the data used in this study), only 205 thousand of 422 thousand men in Navy occupational specialties were career personnel. Thus, a substantial portion of the manpower in military specialties is omitted when the manning ratio is restricted to career personnel.

A major conclusion of this paper is that considerable improvement can be effected in the assignment of VRBs by modifying the manning ratio measure to include non-career personnel. A second conclusion of the

study is that training cost and training time are not now used in the assignment of VRB; the use of these variables would also improve the effectiveness of the VRB. Other findings of the study are developed in the next section where discriminant analysis is applied in order to determine the criteria used by the Navy in assigning VRBs. Summary and concluding remarks are found in the last section.

It should be noted that the paper is directed toward substantive problems, namely, the identification of input variables being used to assign VRBs and input variables that could lead to improvement in the assignment of VRBs. This problem is addressed using discriminant analysis. The emphasis is on the application of this particular area of statistical analysis rather than on its exposition or development.

I. Application of Discriminant Analysis in Identifying Navy Criteria for Assigning Variable Reenlistment Bonuses

In this section discriminant analysis is employed to determine the criteria being employed by the Navy in assigning VRBs. After establishing the utility of discriminant analysis for this purpose, it is then applied to indicate that a different set of ratings would be assigned a VRB if manning ratios were computed based on all personnel instead of career personnel.

To simplify the analysis, skill ratings are separated into two groups depending on whether a variable reenlistment bonus was assigned by the Navy in 1971, and it is assumed that the presence or absence of a Navy assigned VRB is sufficient to distinguish the ratings into critical and non-critical categories. In actual practice, four categories of VRB (one through four, the latter being the highest) are distinguished for computing the dollar value of a VRB.[2] For the present problem, however, all ratings assigned a VRB by the Navy are grouped together and denoted as the V group. All other ratings in which the Navy does not give a VRB are denoted as being in the NV group. Even

[2]The actual dollar value is calculated by multiplying the VRB multiple (one, ... , four) by the first regular reenlistment bonus.

with this simplification, exact replication of the Navy classification is not to be expected using any statistical procedure.

Discriminant analysis is one of a number of procedures for classifying observations (see [1] and [2]). In the context at hand, measurements of variables relating to the criticalness of an occupation are used to classify skill ratings into two categories, one containing ratings designated by the discriminant analysis as being assigned a VRB, the other containing ratings designated as not being assigned a VRB. In this procedure, a linear function of the variables is employed to classify the skill ratings. If the variables are jointly normally distributed within each category, with the same covariance matrices, the linear discriminant function

$$Z = a_1x_1 + a_2x_2 + \ldots + a_nx_n$$

maximizes the difference in the mean values of the linear function for the two categories, relative to the variations of the values of the function within the categories, hence maximizing the probability of correct classification of a rating.

The variables included in the analysis to differentiate the skill ratings are as follows:

X_1: the career manning ratio

X_2: the total manning ratio

X_3: training time in months

X_4: training costs in hundreds of dollars

X_5: the ratio of sea billets to shore billets

X_6: the career reenlistment rate.

As mentioned in the preceding section, the first variable, the career manning ratio, is a measure of the extent to which the supply of and demand for career personnel is in balance. The total manning ratio, X_2, is similar to X_1, but is defined as follows: The numerator is the number of individuals in a given rating who have attained the rank

of E-3 or above; the denominator is the rating requirement for E-3's and above.[3] Since the numerator of this measure includes individuals with less than four year's service, it is no longer restricted to career personnel. In addition, as can be seen, both the numerator and denominator are measured in the same units, i.e., in terms of individuals with rank of E-3 or above.

Training time and training cost, X_3 and X_4, are supply variables which measure the value of the services rendered by a skill rating.[4] Hence, the penalty associated with a given shortage in personnel may be presumed to vary directly with training time and training cost. These are included in the analysis because they are important considerations in the assignment of VRBs, although as indicated below, they are given only negligible weight in the current decision process.

In contrast to the training cost variables, the ratio of sea billets to shore billets, X_5, reflects both supply and demand. On the one hand, sea duty is arduous and requires that individuals be separated from their families; for these reasons, the supply of labor for sea duty jobs may be expected to be smaller than for shore based jobs. On the other hand, the sea/shore billet ratio can reflect demand in that the short-run readiness of the total Navy may be reduced more by an unfilled position at sea than at a land-based communication center or storage facility.[5]

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[3] Both the numerator and denominator exclude "strikers."

[4] Training cost includes basic training and school training costs. For both, the costs taken into account are pay and allowances of students, instructional staff, and overhead personnel; expenses of operating and maintaining facilities and other real property; travel; and accrued leave. These cost figures represent average cost rather than marginal cost, i.e., the incremental cost of training an additional person.

[5] In the long run, however, all things being equal, such as training cost and time, the incremental gain in output resulting from the deployment of an additional person in a specialty with a shortage is likely to be independent of the geographical location of the position being filled.

The sixth variable, the career reenlistment rate, is the percentage of eligible individuals completing two or more enlistment contracts who reenlisted for an additional service tour.[6] This variable which is another measure of supply is utilized in place of the first-term reenlistment rate since the latter reflects the impact of the VRB. Because of this, use of the first-term reenlistment rate can lead to the paradoxical conclusion that all other things being equal, the Navy assigns VRBs to ratings with high first-term reenlistment rates.

The relationship between first-term and career reenlistment rates is seen more clearly from Tables 1 and 2. In Table 1, first-term and career reenlistment rates are shown for ratings with and without a VRB in 1971.

Table 1

Average First-Term and Career Reenlistment Rates, 1971

	Avg. Reenlistment Rate	
	First Term	Career
Ratings with a VRB (V)	20.1	87.5
Ratings without a VRB (NV)	13.8	94.1
Total	17.6	90.1

It is observed that the first-term reenlistment rate of group V ratings exceeds that of group NV ratings. In part this is due to the VRB itself. Additionally, many individuals extend their service period for two or more years to be eligible for training in highly specialized areas, e.g., nuclear technology. The extension of service for two or more years results in these individuals being counted as if they had reenlisted. Both of these factors raising the measured first-term reenlistment rate are, for the most part, absent at the career reenlistment

[6] Notice should be taken of the different definitions of careerists in defining the career reenlistment rate and career manning ratio.

decision point.[7] It is also observed that the career reenlistment rate of group V ratings is lower than that of group NV ratings. Thus, the opportunity cost of continued military service for individuals in the former group of ratings is reflected by the career reenlistment rate rather than the first-term reenlistment rate.[8]

In Table 2, the simple correlation coefficients for the variables entering the discriminant analysis are shown. As suggested by the figures in Table 1, the coefficient between the first-term and career reenlistment rates (FTRR and CRR) are negative and significantly different from zero. Of interest, the coefficients between FTRR and the training cost variables (TT and TC) are positive and significant, contrary to expectations. Here again, the VRB is responsible for reversing the expected relationship. In contrast, the coefficient between CRR and the training cost variables is negative and significant, i.e., as training increases, the individual's earnings potential in the civilian sector increases, and he is less likely to opt for a career in the military. Two additional relationships are worth noting. First, there is a high degree of association between training time and training cost.[9] Second,

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[7] In addition to the direct impact on first-term reenlistment rates, the VRB may exert an indirect impact on career reenlistment rates. The decision to accept a VRB obligates an individual to serve four additional years of service. His decision to reenlist for a third term when he has eight years of military service may be different than his decision to reenlist after four years of service were the VRB not available.

[8] The differential in career reenlistment rates between ratings in groups V and NV would be more pronounced, and the assignment problem would be more amenable to quantitative analysis, were individuals who extended their first enlistment treated as if they had reenlisted and were eligible for a third enlistment after completion of their extended period of service.

[9] Total training cost (see [3]) ranged from $3,312 for the quartermaster rating to $13,557 for the electronics technicians rating, but the range in training cost per year was small. Surprisingly, the training

there is no association between the career manning ratio and the total manning ratio, suggesting the substitution of less experienced personnel for more experienced personnel in those ratings where there is a dirth of careerists relative to requirements. This is to be expected; the absence of such substitution would intensify the problem of meeting the manpower needs of the Navy. But given that substitution of less skilled for more skilled personnel is possible, the most effective way of assigning VRBs would be to offer them in ratings where the supply of highly trained personnel is small and where substitution between skill levels is difficult.

The results of applying the linear discriminant model to the problem of identifying the criteria used by the Navy to assign VRBs are shown in Table 3 for 10 combinations of variables. The variables on the left are the ones utilized in that particular application of the model. The figures in the center of the table are F ratios. They provide a basis for inferring the extent to which the discriminant function classifies skill ratings into categories corresponding to the Navy groupings V and NV . The probability of obtaining an F value as large as the given one is shown at the right. When this probability is small, say, 0.05 or less, it may be concluded that the ratings, defined in terms of the variables in the discriminant function, differ in their criticality in the manner suggested by the Navy groupings V and NV . When the probability of obtaining a given F value is large, larger than 0.05, it can be concluded that the ratings, again defined in terms of the variables in the discriminant function, are drawn from the same population, i.e., are not distinguishable into the disparite criticality categories represented by the Navy groupings V and NV . For example, from line 2, Table 3, it is noticed that when the variables X_1 , X_3 , and X_4 are used, the probability of obtaining an F value as large as 3.08 by chance is 0.05. This small value suggests that these three variables

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costs on a per annum basis were only slightly less for stewards, $10,588, than for aviation fire control technicians, $10,936, reflecting the importance of fixed costs in the estimates.

Table 2

Correlation Coefficients

	CMR	TMR	TT	TC	SS	CRR	FTRR
CMR	1.00	0.11	-0.04	-0.11	-0.09	0.04	0.57**
TMR		1.00	-0.20	-0.22	0.08	0.23	-0.12
TT			1.00	0.85*	-0.10	-0.50*	0.45**
TC				1.00	-0.17	-0.45**	0.44**
SS					1.00	-0.09	-0.15
CRR						1.00	-0.50*
FTRR							1.00

*Coefficient of correlation significantly different from zero at 0.05 level.

**Coefficient of correlation significantly different from zero at 0.01 level.

CMR: Career manning ratio (X_1)

TMR: Total manning ratio (X_2)

TT: Training time (X_3)

TC: Training cost (X_4)

SS: Sea/shore billet ratio (X_5)

CRR: Career reenlistment rate (X_6)

FTRR: First-term reenlistment rate.

Table 3

Discriminant Analysis Results

Line	No. of Ratings	Variables [a]	F Ratio	Probability
1		X_3, X_4	2.23	.25
2	65	X_1, X_3, X_4	3.08	.05
3	65	X_1, X_3, X_4, X_5	3.32	.025
4	65	X_1, X_3, X_4, X_5, X_6	3.56	.01
5	65	X_3, X_4, X_5, X_6	3.23	.025
6	73	X_1, X_5, X_6	4.86	.005
7	63	X_2, X_3, X_4	1.94	.25
8	63	X_2, X_3, X_4, X_5	2.43	.10
9	63	X_2, X_3, X_4, X_5, X_6	2.45	.05
10	70	X_2, X_5, X_6	2.65	.10

[a] See p. 6 for definitions.

provide a basis for differentiating ratings into groups V and NV. On the basis of this result alone, one cannot say whether X_1 or X_3 and X_4 contribute to distinguishing between critical skill and non-critical skill ratings. Line 1, however, indicates that X_1 is the contributing factor rather than X_2 and X_3. When X_3 and X_4 are used to classify the ratings, the probability of obtaining the observed F value is 0.25, i.e., an outcome that could have resulted by chance, e.g., by using an unbiased coin to classify the skill ratings into V and NV.

As indicated by the last column in Table 3, a closer approximation to the Navy assignments is provided by the discriminant function when the sea/shore ratio is included in the model (line 3). An even closer representation of the Navy groupings V and NV is attained when the career reenlistment rate is added (line 4); the F value increases to 3.56 and the probability of observing a value as large as this on the basis of chance is reduced to .01.

The relative weights of the assignment variables can also be inferred from lines 4, 5, and 6. Comparing lines 4 and 5, both the F ratio and the probability of obtaining the observed F ratio is seen to diminish when the career manning ratio, X_1, is removed from the model. Thus, X_1 contributes in a positive manner to differentiating Navy groups V and NV since its exclusion (inclusion) increases (reduces) the likelihood that they were arrived at by chance.[10] In contrast to line 5 where X_1 is eliminated, when the training variables X_3 and X_4 are dropped (line 6), the probability of obtaining the

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[10] Of some interest, comparison of lines 3 and 5 indicates that groups V and NV are distinguished equally well when the career manning ratio or the career reenlistment rate is omitted from the model. As indicated by line 4, an improvement in the goodness-of-fit of the model results when both variables are included.

observed F ratio decreases to .005.[11] On the basis of this small probability, it is concluded that the career manning ratio, the ratio of sea billets to shore billets, and the career reenlistment rate are the primary variables used by the Navy in assigning VRB.

In the discussion above, it has been argued that the manning ratio would be a more meaningful measure of labor market balances if it were based on all personnel rather than being restricted to career personnel. The natural question arises as to whether the replacement of X_1 by X_2 in lines 2-4, 6 permits a mapping of skill ratings into Navy categories V and NV. As can be inferred from lines 7-10, when X_2 is substituted for X_1, the differentiation of the groups is poor. For example, when X_2, X_5, X_6 are used to classify the skill ratings, the probability of obtaining the observed F value is 0.10, again an outcome that could be due to chance. In only one instance (line 9) was the F value low when X_2 is employed. In this case the probability of obtaining the observed F value was .05, but the fit was no better than the poorest fit obtained when X_1 was used. This result can be compared to the case where X_1, X_5, X_6 are used, for which the probability of obtaining the observed F value is very small, .005. The point to be emphasized here is that the same basic approach leads to ratings being grouped in a manner similar to the current Navy assignments when the career manning ratio is used, but the correspondence is substantially reduced when non-careerists are included in the manning ratio.

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[11] In dropping the training variables, the differentiation of the groups V and NV is markedly improved, once again suggesting that training time and training cost play only a minimal role in the Navy VRB procedure, and that the procedure could be improved by giving these variables greater weight.

II. Summary and Concluding Remarks

An increasingly important problem in implementing the all-volunteer force is the development of forms of compensation which facilitate the matching of supply and demand among military skills. One form of compensation which falls into this category is the variable reenlistment bonus (VRB). A non-trivial problem in managing the VRB program is determining the military skills for which this bonus is to be paid.

The objectives of the paper are twofold. The first objective is to identify the variables which "explain" how the Navy assigns VRBs. This is accomplished by using the statistical technique of discriminant analysis. The second objective is to identify variables whose use would improve the assignment of VRBs. In addition to statistical aspects of this problem, this task poses economic questions, namely, how best to measure labor market balances in military labor markets.

By applying discriminant analysis, it appears that the Navy VRB assignments can be explained on the basis of three variables: the career manning ratio, the sea/shore billet ratio, and the career reenlistment rate. The discriminant analysis model also indicated that training cost variables are not adequately taken into account in the assignment procedure. Moreover, it is noted that the manning ratio measure of labor market balance is deficient in a number of respects and can be improved by including non-career personnel. When the manning ratio is defined to include non-career personnel, the ability of the discriminant analysis model to explain the current Navy VRB assignments is markedly reduced. This latter result confirms the supposition that alternative manning ratio measures will yield different VRB assignments.

The utility of multivariate analysis in taxonomic problems has been illustrated many times in the recent past. As indicated in the paper, regardless of whether formal or informal models are used, careful consideration has to be given to the choice of variables used as decision criteria. For the VRB assignment problem, the variables of crucial importance are those which measure labor market balance. As noted, the career manning ratio, which reflects demand as well as supply, is

deficient in terms of definitional consistency and conceptual appropriateness. Additionally, because first-term reenlistment rates reflect the presence or absence of a VRB, the career reenlistment rate provides a preferred measure of reenlistment supply. The career reenlistment rate, however, is not without its deficiencies and can be improved on by including information pertaining to extensions of military service.

Although the issue of effectiveness of the VRB is not taken up in the analysis, discussion of this point cannot be entirely ignored. If the VRB is an ineffective means of raising the first-term reenlistment rate above the level that would otherwise prevail in its absence, the problem of VRB assignment would be an academic one. Hence, some attempt at assessing the effectiveness of the VRB is warranted. For the context at hand, descriptive data suffice. Such data are shown in Table 4.

Table 4

Average First-Term and Career Reenlistment Rates, 1965 and 1971

	Average Reenlistment Rate			
	First-Term		Career	
	1965	1971	1965	1971
Ratings with a VRB (V) [a/]	20.5	20.5	84.4	86.5
Ratings without a VRB (NV) [a/]	24.5	14.9	90.4	94.2
Total	21.6	18.5	86.9	89.5

a/ In both 1965 and 1971.

Recognizing the limitations of a single set of dates in assessing the effectiveness of a particular policy, figures in Table 4 are nonetheless of some interest. They show the first-term reenlistment rate and career reenlistment rate for those ratings where a VRB was assigned in both 1965 and 1971. These can be compared with similar figures for ratings in which no VRB was assigned in 1965 or 1971. As can be seen from these data, between 1965 and 1971 the first-term reenlistment rate remained constant for ratings with a VRB and fell for ratings without a VRB. In contrast, the career reenlistment rate rose for both categories of ratings. The overall decline in the first-term reenlistment rate most probably is due to the Vietnam War. The rise in the career reenlistment rate is harder to explain. The explanation may be as simple as an easing of constraints on potential careerists in order to meet strength requirements, or it may be due to increases in military retirement benefits and expected post-military civilian earnings which are making career service in the military sector more desirable. Although of interest, these trends are beyond the scope of our discussion.

The figures in Table 4 reveal other differences which are more pertinent to the discussion. Whereas career reenlistment rates rose less (more) rapidly for ratings where a VRB was (was not) offered in 1965 and 1971, first-term reenlistment rates fell less (more) rapidly for ratings where a VRB was (was not) offered at both dates. The slower rise in career reenlistment rates in ratings where a VRB was offered, despite the indirect effect of the VRB to raise the career reenlistment rate, suggests that the opportunity cost of a career in these military skills, i.e., the expected earnings in similar skills in the civilian sector, has increased vis-a-vis those military skills where a VRB was not offered. On the other hand, the first-term reenlistment rate fell only slightly for VRB ratings whereas it fell dramatically for non-VRB ratings. It would appear that the provision of compensation differentials in the form of VRB payments and/or the rise in such payments, due to increasing military base pay and increases in the VRB multiple,[12] has had a positive

[12] Between 1965 and 1971, the VRB multiple (see fn. 2, p. 4) increased in 18 of the 26 ratings in which a VRB was offered at both dates.

retention influence. Although the data in Table 4 are not conclusive, they are consistent with the hypothesis that the VRB was a factor cushioning the potential decline in first-term reenlistment rates among ratings in which it was offered. The findings of this paper suggest some first steps in increasing the magnitude of the positive impact of the VRB.

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- Data Solutions Corporation
- Decision Systems Associates, Inc
- Denver Research Institute
- Hudson Institute
- Management Analysis Center, Inc
- MATHEMATICA, Inc
- Operations Research, Inc
- Personnel Decisions, Inc
- Princeton University
  - Prof. G. S. Watson
- The RAND Corporation
- Stanford Research Institute
  - Naval Warfare Research Center
- Systems Development Corporation
- Univ of California, Berkeley
  - Prof. Robert M. Oliver
- Univ of Michigan
  - Dr. David G. Bowers
- Univ of Pennsylvania
  - Dr. Herbert R. Northrup
  - Prof. Ezra S. Krendel
- USN Pers & Train Res Lab, San Diego
  - Dr. Norman M. Abrahams
- USN Postgrad School, Monterey
  - Dr. Jack R. Borsting

NAVY
- Asst Secretary of the Navy (M&RA)
- ACNP, Enlisted Force Analysis
- ADCNO (Manpower)
- Defense Documentation Center
- Manpower Train & Res Group (Op-964D)
- Chief of NavAir Train, Pensacola
- Chief of Nav Train, Pensacola
  - CAPT Allen E. McMichael
- Chief of Nav Tech Train, Millington
- Naval Appl & Analysis Div (460)
- Naval Development
- Naval Education and Training
- Naval Material Command (03PB)
- Naval Material Command (03424)
- Naval Medical Neuropsychiatric Res
- Naval Medical Res Institute
  - Behavioral Sci Dept
  - Tech Ref Library
- BUMED
  - Chief, Res Div
  - Code 513
- Naval Operations (Manpower)
  - Op-01BZ2
- DCNO (M&RA)
- BUPERS
  - PERS 222e
  - Dir, Career Info & Publ Div
  - Dir, Career Motivation
    - Plans & Prog Div
  - Pers & Train Res Lab, San Diego
  - Dir, Pers & Train Res Prog
  - Pers & Train Support
  - Asst for Pers Logistics
  - Sp Asst to Chief NavPers (Oe)
  - Asst Chief of NavPers
    - Plans & Prog